Breeding Forest Trees For Pest Resistance

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Success in the development of pest resistant forest trees holds out promise that tree breeding may alleviate at least part of the pressures from disease organisms and insects. Forest tree breeding is a relatively new art. The first formalized research in this country took place only about 40 years ago. In the past 10 years, research in forest genetics has increased many-fold and breeding for pest resistance is a major objective in many programs.

Tree-Breeding Procedures

The development of improved forest trees is a difficult, often frustrating, and time-consuming undertaking. The selection of resistant trees requires extensive examination of forests to search for the rare tree which may carry the genetic tendency for resistance. Then only by controlled breeding and progeny testing can it be established that the resistance is in fact inherited, and that the healthy tree had not escaped attack.

The process of creating hybrids, in conifers, requires many trips up and down trees to protect the immature female strobili from stray pollen, to collect the desired pollen, to pollinate the female strobili, to remove the pollination bags, and finally to collect the cones (Cumming and Righter, 1948).

In the pines, in which most research is being conducted, this procedure lasts for about a year and a half. The female strobili mature during the period from February or March until May, depending on the latitude, altitude, and species, and are receptive for pollination for only a few days. Fertilization occurs after 12 to 14 months, in the year following pollination, and cones and seeds mature several months later.

Seeds are usually sown in the nursery in spring, and seedlings emerge in a few weeks. Seedlings can be tested for resistance to fungi or insects in one to several years under artificial or natural conditions, although it may take many years to test for some pests. Ten to twenty years or more must pass before a second generation can be produced in some species. But these difficulties have been overcome and pest-resistant trees have been developed.

Breeding for Disease Resistance

Many of the disastrous diseases of forest trees in the United States resulted from organisms brought in from other continents. Our native species had no opportunity to evolve to this new part of the environment by natural selection. Thus the organisms causing white pine blister rust, chestnut blight, and Dutch elm disease found highly susceptible hosts here. Other native diseases, endemic normally, flair up under changed environmental conditions of intensive management for wood production or when a favored host is moved out of its natural range.

Forest geneticists are developing resistant trees by two procedures. Selecting the rare individual which, through some genetic change, is resistant to the disease organism has been most productive. Producing interspecific hybrids between the susceptible native species and immune or resistant exotic or native species has also shown promise.

Western white pine (*Pinus monticola*) is extremely susceptible to the organism causing white pine blister rust (*Cronartium ribicola*). In the millions of acres of infected trees in Idaho, a few hundred scattered trees were found in epidemic areas which bore no disease cankers (Bingham, Squillace, and Duffield, 1953). Controlled breeding among these resistant candidates has shown that about one quarter of the selections are able to transmit their resistance to their offspring. Narrow-sense heritability was found to be high, and the genetic gain in survival was estimated to be about 20 percent per breeding generation (Bingham, 1960). The results of this research are so encouraging that seed orchards are being established to produce seed for trees with substantially greater resistance to the blister rust fungi. Similar research is underway for sugar pine *(P. lambertiana)* and eastern white pine *(P. strobus)*, the two other important native white pines.

Some exotic white pines are highly resistant to the blister rust fungus. They have been used in interspecific hybridization in an attempt to incorporate resistance factors in the hybrid. Himalayan white pine *(P. griffithii)*, has been crossed with eastern white pine and the progeny are more resistant than the American parental species (Callaham, 1962).

Even better prospects exist for developing trees resistant to a native rust, *Cronartium fusiforme*, which severely attacks two important southern pines—loblolly (*P. taeda*) and slash (*P. elliottii*). Rust-free trees have been located in heavily infected stands. Progeny of rust-free parents had markedly fewer infections under heavy artificial inoculation with the fungus than did progeny from infected parents (Jewell, 1961).

Also, the possibility exists for mass production of interspecific hybrids between these two susceptible pines and the resistant shortleaf pine (*P. echinata*). Shortleaf pine x loblolly pine hybrids showed no rust cankers after five years in an area of heavy infection on slash pine (Henry and Bercaw, 1956). In subsequent trials under forced inoculation, cankers did develop on both this hybrid and the hybrid between shortleaf and slash pines (Jewell, 1961). But infection was not nearly as severe as on the slash or loblolly pine seedlings.

Progress is being made in breeding forest trees which are resistant to *Endothia parasitica*, the causal agent of chestnut blight. This imported disease has practically destroyed the American chestnut (*Castanea dentata*). A few trees apparently have survived attack and may constitute the basis for developing a resistant strain (Anderson, 1960). Some hybrids between the American chestnut and the Japanese chestnut (*C. crenata*) and the Chinese

Figure 1. A forest geneticist squirts pollen over the female strobili, which are protected from stray pollen.

Figure 2. A western white pine tree which has been control-pollinated to produce blister-rust-resistant trees.

chestnut (*C. mollissima*), the most resistant species, are resistant to the fungus. However, most of these hybrids have relatively poor form for timber trees and need a better site than did the native chestnut (Gravatt et al., 1953).

Although the poplars are not particularly important now as timber trees in this country, they have great potential for rapid growth. They also are beset by many diseases. In Europe, poplar culture is often very intensive and breeding for disease resistance has long been a part of growing poplar. As a result, a number of clonal lines have been developed to resist many of the disease organisms (Schreiner, 1959). Poplars are easily propagated by cuttings and perpetuation of resistant strains is easy.

Less progress has been made in breeding other trees to withstand disease organisms. For example, little progress todate has been made in breeding against the organisms causing Dutch elm disease (*Ceratocistis ulmi*) or oak wilt (*Ceratocystis fagacearum*). Breeding against any of the multitude of heart rots, which cause damage in the billions of board feet annually, has not yet started. But these endeavors are not impossible even though success may be a long time off.

Breeding for Insect Resistance

Natural variation exists within many tree species with respect to susceptibility to insect attack. Immunity of some tree species to attack by a given insect also provides the basis for developing strains of hybrids resistant to insect pests. In the Northeastern and Lake States, eastern white pine is so severely damaged by the white pine weevil (*Pissodes strobi*) that profitable management of white pine is uncertain. This insect repeatedly attacks the terminal of saplings, causing trees of very poor form. Enough trees have resisted attack to justify a breeding program (Wright and Gabriel, 1959).

In California, plantations of ponderosa pine (*Pinus ponderosa*) and Jeffrey pine (*P. jeffreyi*) have suffered severely from killing by the pine reproduction weevil (*Cylindrocopturus eatonii*). Coulter pine (*P. coulteri*), native to California, is immune to the insect. Hybrids between Jeffrey pine and Coulter pine were attacked by the insect but not killed under conditions in which all Jeffrey pine trees were killed (Miller, 1950; Callaham, 1960). Planting results with these hybrids in California have been successful enough that the Forest Service has started a program to produce hybrid seed.

The valuable red pine (*P. resinosa*) of the Lake States is considered to be extremely susceptible to the European shoot moth (*Rhyacionia buoliana*). A closely related species, Austrian pine (*P. nigra* var *austriaca*) is the least susceptible (Holst, 1963). All attempts to hybridize red pine with other pines in its group (*Lariciones*) failed until recently. In 1962 the red pine x Austrian pine was created (Critchfield, 1962). One might expect that these hybrids will be intermediate between the parents in their susceptibility to the shoot moth.

In the South, loblolly and shortleaf pines are attacked by the Nantucket tip moth (*Rhyacionia frustrana*), but longleaf and slash pines are quite resistant species. Interspecific hybridization provides opportunities for improvement.

Recent research shows that we should be able to produce pines which are resistant to the very destructive bark beetles. The susceptibility of pines to bark beetles varies greatly among species and even within a host species. Because bark beetles attack relatively mature trees, the determination of resistance could be a longtime procedure. To shorten this testing period, forestry scientists looked for the causes of resistance. They now believe that resistance is due to the composition of the terpenes of the gum which exudes into the gallery made by the attacking beetles. Terpenes vary in kind and relative amounts in the pines. Some bark beetles are very sensitive to certain terpenes but can tolerate large amounts of others (Smith, 1961). With the toxic terpenes known, resistant young trees or even seedlings can be identified quickly by gas chromotography from even a drop of gum.

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